Gamma-ray emission in the spontaneous fission of 252Cf and in the induced fission of 229Np* (fission time scales)

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Chapter 10

229Np*: Conclusion

From our experiments, ^{20}Ne on ^{209} at beam energies 150, 186 and 220 MeV, the following conclusions can be drawn. Good fits to the data have been obtained with the modified statistical code CASCADE [But91], by using a "dynamical" fission time of a few times 10^{-19} seconds. A large enhancement in the γ-ray emission probability at energies above 8 MeV is observed when going from the 150 MeV to the 186 MeV experiment. Since the γ-ray energy spectrum above 8 MeV is primarily due to γ-rays emitted from the fission fragments, this increase in the γ-ray emission probability above 8 MeV implies an increase of the excitation energies at scission. This observation can be correlated to a decrease in the "dynamical" fission time scale. The fission time scale in the 150 MeV experiment is found to be 2 to 4 times longer than that at the 186 beam energy experiment. When comparing the 186 MeV and 220 MeV experiments, the γ-ray yields for $E_\gamma > 8$ MeV are similar. This implies that the excitation energies at scission are approximately equal. It can be explained by using similar "dynamical" fission times in the calculation of the γ-ray energy spectra observed in these two reactions.

The fission delay times deduced from our work are:

- 150 MeV: $\tau_{fiss} = (4 \pm 1) \ \times 10^{-19}$ seconds.
- 186 MeV: $\tau_{fiss} = (1 \pm 0.5) \times 10^{-19}$ seconds.
- 220 MeV: $\tau_{fiss} = (2 \pm 1) \ \times 10^{-19}$ seconds.

The angular dependance with respect to the spin axis, measured for the reaction ^{20}Ne on ^{209}Bi at a beam energy of 220 MeV, is best reproduced by introducing an oblate deformation with $\beta = 0.4$. However at high energies the calculated anisotropy is too small and can not be enhanced within the model used, which assumes axial symmetrical shapes.

The pre-scission neutron multiplicity, deduced from the calculated γ-ray spectra, are slightly higher than the systematics of measured pre-scission neutron multiplicities in other systems.

The deduced fission delay times are in good agreement with those deduced from the neutron measurements. They are also in good agreement with the fission delay time deduced, with the same statistical code, from fitting the γ-ray spectrum of the reaction ^{16}O on ^{208}Pb at a beam energy of 120 MeV [Pau94].

• **Open questions**

The performed experiments can not answer questions as to where during the fission process one needs the necessary fission delay time, during formation, pre-saddle or saddle-to-scission. Neither can it answer questions as to where during the fission process the statistical probability for fission is decided upon. These two questions might be correlated.

The statistical fission probability decreases rapidly with decreasing excitation energy. Thus where in the fission time the decision to fission is made, before or after one invokes a fission delay, has drastic consequences for the fission versus residue cross section. Thus a simultaneous measurement of the residue cross section with pre-scission particle and/or γ-ray multiplicities will supply more information on the fission process.

The relative neutron versus either charged particle or γ-ray emission might supply further information on the average nuclear shape and/or excitation energy during which these particles or γ-rays are emitted. The liquid drop model predicts decreasing (increasing) effective particle binding energies for neutrons (charged particles) with increasing deformation [Les91, Les93].

In order to obtain more information on the fission process one needs to combine different kinds of measurements. For instance by combining measurements of the residue cross sections along with measuring pre-scission particle or γ-ray multiplicities or by measuring simultaneously at least two different pre-scission multiplicities.